Framework for Developing a Regional System Architecture for Intelligent Transportation Systems

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Defining an architecture for intelligent transportation systems (ITS) at the regional level, where most ITS deployment occurs, is constrained by jurisdictional, institutional, financial, political, and regulatory factors. These constraints provide opportunities for the architecture that go beyond its traditional role as a guiding tool for technology implementation to a newer role of reorienting institutional relationships. An architecture development approach is proposed that considers regional transportation needs and characteristics so as to increase the benefits from implementing ITS locally. It also provides a new way of thinking about the importance of the National ITS System Architecture in the context of regional ITS deployments. The development approach was tested by considering how regional architectures in New York, Boston, and Houston address regional needs. Findings and implications of the regional ITS architectures of the case study areas are presented.

A system architecture, a framework that brings major stakeholders and strategies together to achieve a set of tasks, has been chosen in the United States as a guide to the deployment of Intelligent Transportation Systems (ITS). ITS applies emerging and established technologies to achieve reductions in congestion, improvements in safety, and other benefits in surface transportation, but it requires the deployment of complex, integrated technology-based systems (*1*).

A system architecture can guide the technology deployment process by allowing better agency and user choices, facilitating service integration, and encouraging market competitiveness by facilitating technological compatibility (*2*). The main steps in defining a system architecture are to

- Define the tasks the system should perform (system requirements) and the main steps to achieve those tasks (functional requirements);
- Identify the subsystems and end users involved; these subsystems include institutional, technological, and physical systems;
- Assign functional requirements to individual subsystems; and
- Develop an understanding of integration, interrelationship, and interdependencies among the subsystems. Information exchange requirements and data flows are typical examples of interaction among subsystems.

The recent completion of a National System Architecture for ITS deployment by the Loral (now a part of Lockheed Martin) and Rockwell teams is a step forward in the ITS implementation process in the United States (*3*). Actual deployment of ITS, however, is expected to continue at the regional level.

Such regional deployment requires some level of coordination among regional agencies. Coordination can lower costs and provide added functionality and services that positively affect user market penetration and enhance transportation operations. A regional system architecture for ITS deployment is a tool that can facilitate the regional coordination task. A regional architecture represents the interaction between agency-specific ITS deployments and broader objectives addressed in a regional transportation plan. It introduces the National ITS System Architecture to the regional arena by including constraints and localized transport priorities in the architecture laid out nationally. In this way, the National ITS System Architecture will serve its intended role of broad blueprint for ITS deployment that will occur at the regional level by addressing regional needs (*4*). Furthermore, a regional architecture for ITS deployment can also serve as an instrument for redefining institutional roles related to technology deployment, maintenance, and its management.

FRAMEWORK FOR DEVELOPING A REGIONAL ITS SYSTEM ARCHITECTURE

A framework for developing a regional system architecture is described. The framework uses the National ITS System Architecture and regional characteristics and needs as its main inputs (*5*).

The first input, the National ITS System Architecture, provides some degree of consistency among regional architectures. In principle, if regional architectures around the United States are derived from the National ITS System Architecture, the chances of reaching national interoperability would increase. Other conditions for regional architectures, such as the incorporation of emerging National Architecture–based standards, must also hold in order to achieve national interoperability. Local characteristics, the second input, allows for defining the regional architecture in the context of regional needs and objectives.

Figure 1 depicts the framework developed and its inputs. The framework recognizes the relevance of the National ITS System Architecture as a facilitator of the regional architecture definition process.

The framework depicted in Figure 1 takes into account local characteristics, such as political, economic, and social constraints that are intimately associated with the needs of a region. Within this framework, the regional architecture can respond to localized needs and requirements. These characteristics are depicted in the upper left box of the figure.

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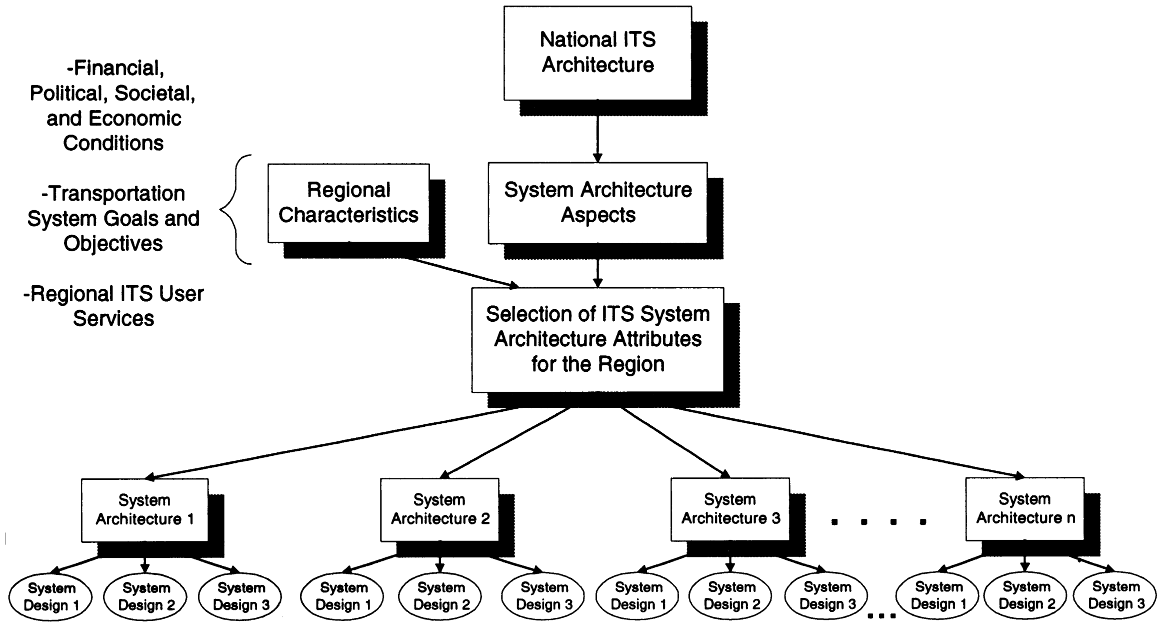

FIGURE 1 Depiction of framework for developing a regional ITS system architecture.

The top box in Figure 1 depicts the contribution of the National ITS System Architecture to the definition of a regional architecture. The strength of the National ITS System Architecture is that it spells out a general guide for deploying ITS while allowing for localized choices. The level of nationwide equipment compatibility will depend largely on the regional ITS deployer's acceptance of the National ITS System Architecture. Benefits from the National ITS System Architecture are maximized if players involved in the deployment of ITS realize that there is value in complying with the architecture and its associated standards.

The National ITS System Architecture feeds into the system architecture Aspects box. An architecture aspect is defined as a general high-level concern about the architecture. *Aspects* may be thought of as technical and institutional questions about the architecture such as, Which regional subsystems need to interact, to what extent, and how? or What are the range of user services that could be offered? These aspects are critical to the development of a regional architecture. From the technical perspective, aspects involve determining the subsystems, their functionality, and information flows. The technical work documented in the National ITS System Architecture lends itself as a natural blueprint for identification and development of technical architecture aspects.

From the institutional perspective, aspects involve more strategic questions such as, What level of interagency cooperation is desired and what level is feasible? or Should all surface transportation modes be included in the system architecture? There are two ways in which the National ITS System Architecture influences institutional aspects. First, the National ITS Architecture describes itself in the interaction between institutional and technical aspects. For example, technical aspects such as associated standards and common interfaces related to the National ITS System Architecture allow for varying institutional arrangements. Those institutional arrangements, in turn, affect other technical aspects, such as subsystem functionality and information flows. Second, the National ITS System Architecture brought strategic technical and institutional issues to the regional discussion table. Therefore, the links between technical and institutional aspects can be understood better in light of the National ITS System Architecture.

Juxtaposing the architecture aspects derived from the National ITS System Architecture with the regional characteristics allows for identifying and selecting ITS architecture attributes, as shown in the center box of Figure 1. The two inputs, architecture aspects and regional characteristics, feed into the architecture development process, and the desired architecture attributes are selected. An architecture attribute is a specific feature of the architecture that could be thought of as a response to questions posed by architecture aspects. An attribute is a specific choice about the architecture that is related to both institutional and technical aspects. Trade-offs are implicit in going from an architecture aspect to selecting a specific attribute. For example, the aspect defined previously as "What level of interagency cooperation is desired and what level is feasible" can be linked to two attributes:

- Degree of coordination in the deployment of ITS, and
- Degree of coordination in the operations of ITS.

A region bases decisions about these attributes on the region's characteristics and priorities. Other examples of architecture attributes that stem from architecture aspects can include "The system architecture covers all modes and their respective interaction—it is intermodal" and "The user services will be independent of each other." A set of aspects and their corresponding attributes are identified in the case studies section.

The framework makes a clear distinction between what we have called architecture *aspects* and architecture *attributes*. This distinction became instrumental when analyzing the case studies because it allowed for clearly distinguishing the architecture options (the aspects) from decisions about the architecture (the attributes). This conceptual separation also helped in bounding the scope of influence that can be attributed to the National ITS System Architecture, represented within the framework by the architecture aspects.

Architecture attributes at the regional level then become inputs to a final definition of a regional ITS architecture. Several architectures could be implemented on the basis of a given set of attributes for a region, as depicted by the boxes in the lower half of Figure 1. These architectures, in turn, can also be implemented differently through unique system designs. Many system designs can work for a given architecture.

The proposed framework for developing a regional ITS architecture conveys a regionwide strategic character; a regional architecture can be a part of, or become, a multimodal and intermodal overarching strategic plan for regional transportation. Consideration of a region's transportation objectives and needs implies close ties with regional transportation planning in the long term and the short term. In fact, the case studies presented in the next section used long-range regional transportation plans and transportation improvement programs to identify regional transportation priorities and study their correspondence with the regional architectures.

Another example of the connection between a regional ITS architecture and transportation planning is how the architecture can become a much-needed coordinator of multiple agency and modal-specific strategic plans that have often proliferated with no consistency or connection. Furthermore, development of a regional architecture can be viewed as a necessary component of a truly regional transportation plan that considers ITS as an integrating element of future transportation investments.

CASE STUDIES

The regional system architectures of three U.S. metropolitan areas—New York, Boston, and Houston—were selected for study. The influence of the National ITS System Architecture on regional architecture aspects could not be assessed in the case studies because the regional architectures were developed before the National ITS System Architecture. Rather than hypothesize on how the National Architecture could have influenced regional ITS architecture decisions, the study concentrated on assessing the consistency between the regional architectures developed and regional characteristics and needs.

Aspects Considered

The assessment focused on four specific architecture aspects that the authors judged to be particularly important:

1. Interjurisdictional cooperation and coordination,
2. Degree of interdependence among regional ITS services (commonly known as user services),
3. Institutional requirements, and
4. Architecture's degree of intermodalism and the role of transit in the architecture definition process.

These four aspects, all jurisdictional and institutional in nature, highlight regional issues that are key for planning regional deployment of ITS. The information used for the cases was gathered through personal and telephone interviews, as well as publications, papers, and plans that document each region's characteristics and its architectures.

Interjurisdictional Cooperation and Coordination

The level of interjurisdictional cooperation and coordination needed in developing the architecture and implementing the necessary ITS applications is important because it influences the effectiveness of delivering ITS services. These effects are particularly relevant in larger metropolitan areas, where travelers and freight often cross multiple jurisdictions. The related issue of the level of technical knowledge needed to implement the architecture is also relevant. A regional architecture should be understandable to implementing agencies. Necessary interaction cannot take place if parties involved do not understand their own relevance in the process.

Trade-offs associated with interjurisdictional cooperation are related to the speed of deployment versus the legitimacy and inclusiveness of the architecture. In regions where transportation agencies are highly autonomous, an architecture that requires significant integration efforts among agencies can encounter opposition.

Degree of Interdependence of ITS Functions (User Services) for Region

Development of an architecture encounters the ubiquitous trade-off of cost versus level of service. An architecture that provides the flexibility to enable significant expansions in services and users is more complex than an architecture geared toward specific services. The added level of complexity creates costs that can be offset by the additional flexibility of supporting more services. The degree of interdependence among user services determines the need for regional coordination in deploying and operating ITS.

Two alternative architectures are a stand-alone architecture and a platform-based architecture. These two attributes relate to the interdependence of ITS user services. A stand-alone architecture supports few and specific user services (e.g., electronic toll collection). In a stand-alone architecture, equipment interoperability between services supported by the architecture is more easily achieved because of its concentration on few user services. There can be as many stand-alone architectures as there are user services to support them. Deployments based on stand-alone architectures can be very cost-effective for the services supported but do not provide growth paths for future user services.

In a platform-based architecture, user services are enabled by any number of existing technologies. The services can be updated as technology changes. A platform-based architecture allows the use of various technologies suited for different services. As user services are developed, the base or platform is used to include the new development.

Contrasting both attributes suggests that a stand-alone architecture has a shorter life span, is less flexible, and may be less costly for the particular service being provided than a platform-oriented architecture. On the other hand, a platform architecture provides flexibility to accommodate future services and uses the platform to provide many services at less total cost than would be possible through many stand-alone architectures.

Degree of Architecture Intermodalism and Role of Public Transportation in Architecture Definition

A system architecture can be unimodal, multimodal, or intermodal, depending on the type of transportation modes encompassed by the architecture definition. Decisions about a unimodal, multimodal, or intermodal architecture character should be consistent with the needs of the region and its transportation system.

Defining an intermodal architecture—for passenger and freight transport—is complex because the architecture would encompass the interaction among modes. This means not only addressing additional issues of technological compatibility and standardization, but also dealing with agencies that traditionally may have been autonomous in their decision-making processes. A strength of an intermodal system architecture is that it can rationalize modal interaction.

Particular attention in this assessment was paid to the role of public transportation in both the development of the system architecture and its modal coverage. Caskey noted how the National ITS System Architecture was not helpful, initially, to public transportation agencies because of the way that user services were being grouped together (*6*). This finding raised concerns about the modal inclusiveness of the architecture. Evidence from the case studies conducted in this research suggests that transit agencies have not played an important role in the regional deployment of ITS.

Institutional Requirements of Regional Architecture

The main elements of the regional aspect are the critical institutional issues associated with ITS deployment. This includes the modification of responsibilities of existing agencies and the creation of new agencies to carry out other functions.

Regional coordination and ITS deployment planning is explicitly addressed by a regional system architecture. Two distinct attributes associated with institutional roles can have effects on the ITS services provided: creating a completely new organization for ITS deployment, and assigning ITS-related roles and responsibilities to existing organizations.

Regional Characteristics of Case Study Areas

Urban Characteristics

The Boston, Houston, and New York metropolitan areas differ in population and geographic area. These characteristics are useful in studying how an architecture for ITS can be affected (if at all) by the size of the metropolitan area. The cities, in addition, are in different stages of urban development. New York and Boston are mature cities with active urban core areas; Houston is a relatively young city with a developing core metropolitan area.

Transportation System Characteristics

Each of the three regions has a multimodal transportation system that includes various passenger and freight modes. Boston and New York have extensive public bus and rail services. Houston's development, on the contrary, has been based on the automobile. In the future, efforts to improve and promote transit services in Houston may provide services that are more balanced between automobile and transit.

The regions exhibit transportation policies that differ greatly. New York and Boston have transit services concentrated on high-density, high-ridership corridors. The automobile provides mobility in the suburbs. Even though Houston contains a vast network of high-occupancy vehicle (HOV) lanes and transit centers, it continues to exhibit a reliance on private automobile for travel and limited support for public transportation services.

For freight movements, each region depends very heavily on trucking. The three regions selected could all be considered as international gateway cities to the United States in terms of freight and passenger transportation, with large airport and seaport facilities.

Institutional Characteristics

Intricate institutional and regulatory relationships characterize the governance of major metropolitan areas; these three areas are no exception. New York's size and scope and Boston's political tradition create complex institutional and regulatory issues. Houston's experience with the role of the private sector in building coalitions with the public sector to improve urban conditions in housing, economic development, and transportation, among other sectors, indicates the willingness of major regional stakeholders to find innovative solutions and reach high levels of interinstitutional cooperation.

Case Studies

New York Region

On a regional basis, 14 transit, highway, and public safety agencies in the New York metropolitan area signed a memorandum of understanding creating a consortium called Transportation Operations Coordinating Committee (TRANSCOM). The main services currently offered by TRANSCOM can be summarized in three areas: information dissemination, regional construction coordination, and technology development. TRANSCOM has limited its operations to gathering and disseminating information with no command power over other regional agencies. A graphical representation of TRANSCOM's system architecture is presented in Figure 2.

Houston Region

The Houston Transtar, formerly the Greater Houston Traffic Management Center, was created by existing public agencies to respond to the identified need of having a centralized transportation management center. The Texas Department of Transportation (TxDOT), Harris County, Metropolitan Transit Authority of Harris County (METRO), and the city of Houston initiated the Greater Houston Traffic Management Center. Transtar is an organization for facilitating interagency coordination of joint response activity. It is also in charge of coordinating the deployment and operations of several ITS deployments with other regional transportation agencies and private providers. A graphical depiction of Houston's Transtar architecture is provided in Figure 3.

Boston Region

In 1994 the Massachusetts Executive Office of Transportation, in conjunction with the Massachusetts Highway Department (MHD), developed a strategic plan for deploying ITS. The tasks included identifying the most relevant regional needs, highlighting applications that can assist in supplying those needs, developing a system

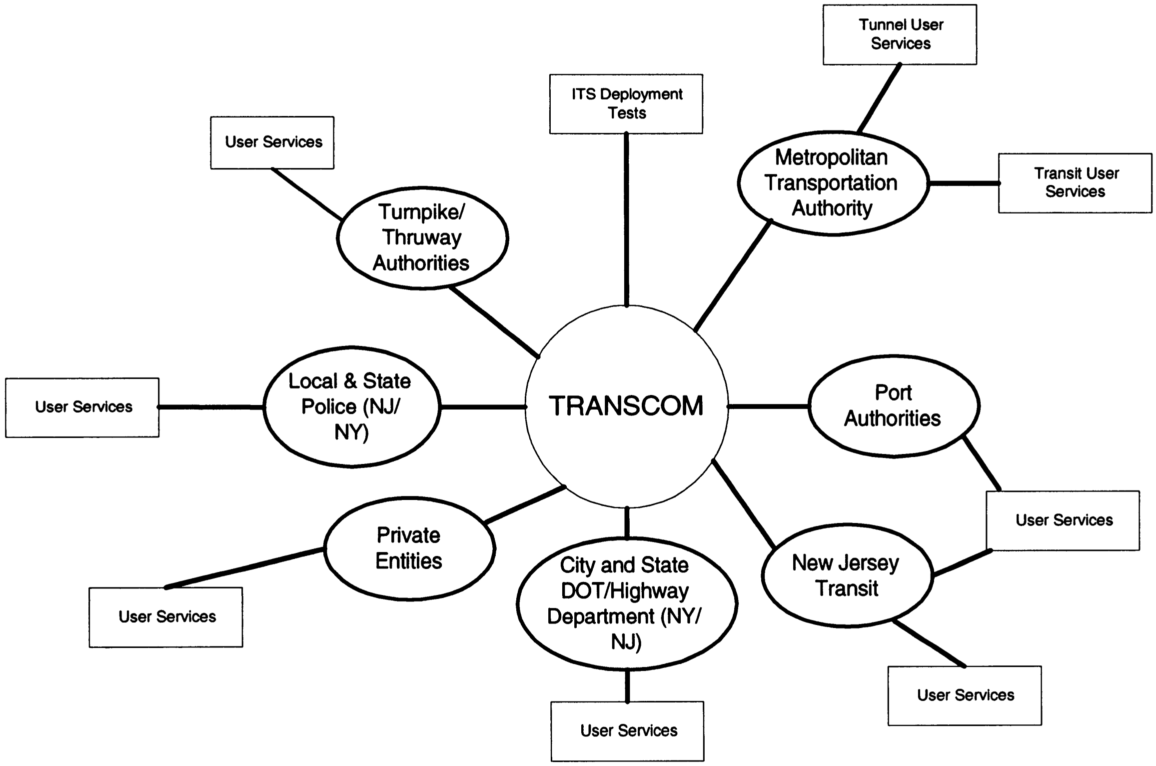

FIGURE 2 New York metropolitan region system architecture for ITS.

architecture to coordinate the deployment of the applications, and proposing a short-term implementation plan. The regional architecture, shown in Figure 4, is a direct outcome of Boston's ITS strategic plan.

Architectures

Table 1 provides a summary of the architecture attributes observed for the three case studies. Houston opted for creating a new agency to coordinate ITS deployment. Houston's architecture shows how its new agency, Transtar, is involved not only in coordinating deployment but also in either operating multiple ITS user services directly or sharing responsibilities with other regional agencies. Boston's architecture proposed a new agency that has not yet been created. New York's agency, TRANSCOM, existed before the development of the area's architecture.

The three architectures recognize the importance of the autonomy of existing transportation agencies in different ways. The New York and Boston architectures (depicted in Figures 2 and 4, respectively) assign ITS deployment and operation responsibilities to individual modal agencies. The regional coordinating agency has very limited control over the operation of ITS user services. In Houston, even though agencies also retain autonomy in deployment decision making, highway and transit operations are colocated in Transtar's facilities. This represents a departure from the traditional modal separation of transportation operations and planning. The ability of Houston's ITS-coordinating agency to deploy and operate user services is depicted by the shape of the architecture presented in Figure 3.

In Boston (Figure 4) the architecture does not assign user service deployment or operation responsibilities to the regional Transportation Information and Coordination Center (TICC). Although Boston's architecture is highly hierarchical, limited command and control powers assigned to the TICC were proposed by the architecture developers. These command and control functions complement the proposed TICC's information and advisory functions and should be exercised only during emergency situations.

The shape of the New York region ITS architecture (Figure 2) responds to its information and advisory functions. The sketch is characterized by a highly centralized architecture in which TRANSCOM serves as a regional information clearinghouse, with command or control power over neither regional transportation agencies nor any ITS applications.

Different degrees of intermodalism are observed in the architecture case study areas. Houston's Transtar exhibited a high degree of intermodalism in the passenger modes with its two cornerstones, METRO and TxDOT, representing transit and highway passenger modes. Boston's TICC and New York's TRANSCOM have lower degrees of passenger intermodalism, as transit agencies have been less involved in ITS coordination of the architecture user services.

FINDINGS

This section summarizes the major conclusions and observations drawn from the three case studies. Determining whether the ITS architectures studied are consistent with regional characteristics and priorities involves considering the passenger and freight modes in each region. The authors do not attempt to judge the transportation and land use priorities for each region; instead, they observe the different subsystems and study the way each architecture addresses them. Conclusions presented are a result of assessing the consistency

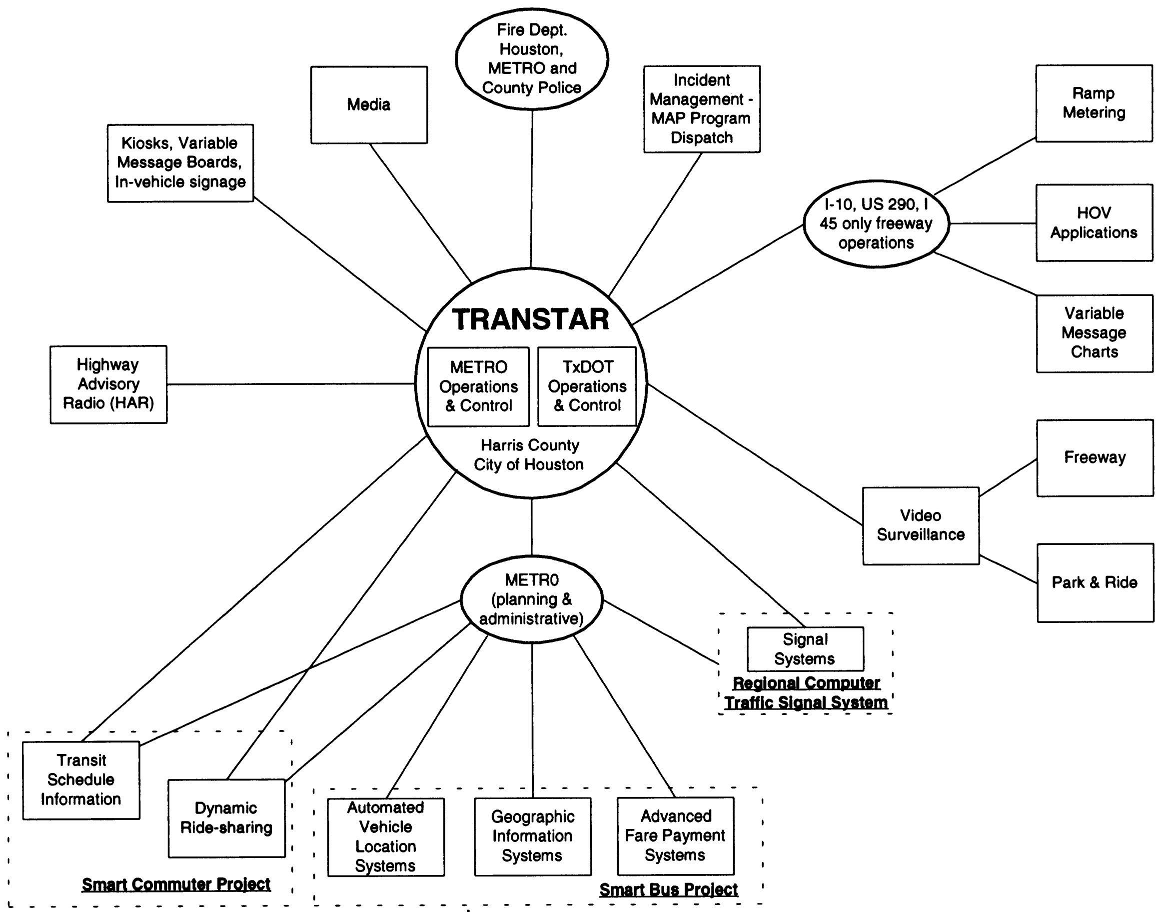

FIGURE 3 Houston metropolitan region system architecture for ITS.

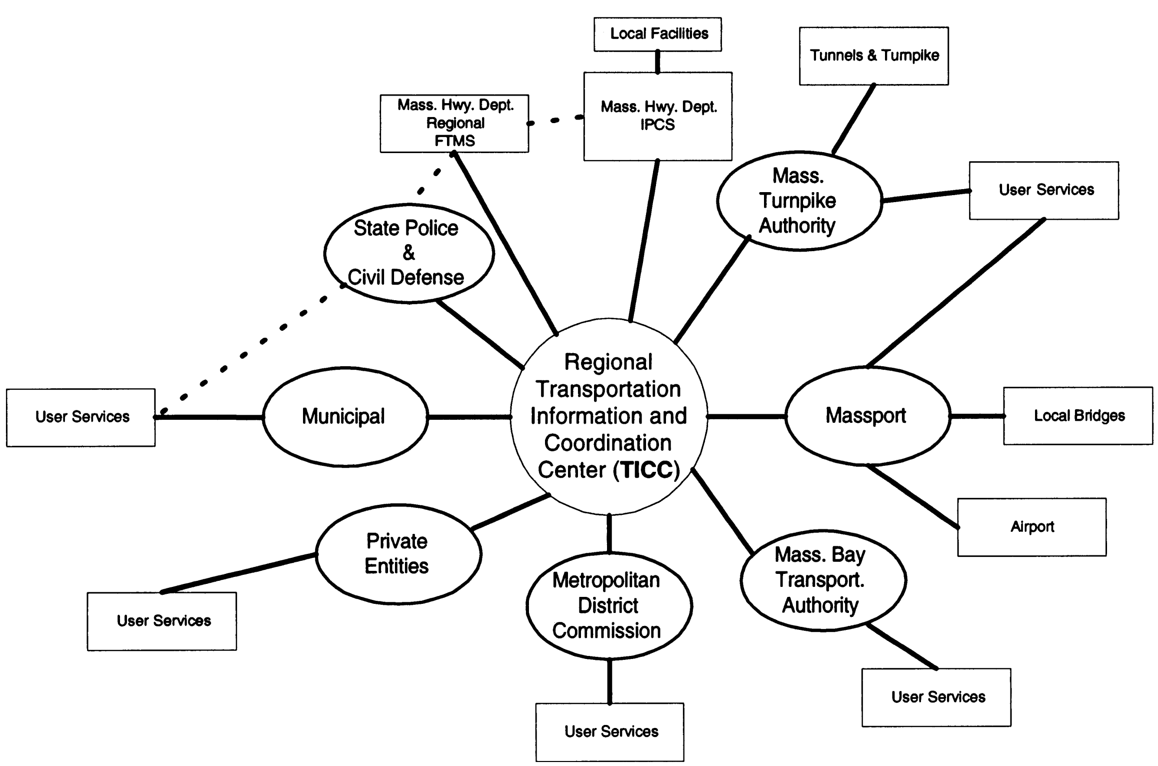

FIGURE 4 Boston metropolitan region system architecture for ITS.

TABLE 1 Observed Architecture Attributes for New York, Boston, and Houston Metropolitan Area Case Studies

ARCHITECTURE ASPECTS AND ARCHITECTURE ATTRIBUTES OBSERVED								
Architecture ASPECTS	Interjurisdictional Cooperation and Coordination		Institutional Requirements		Regional User Services		Architecture Inclusiveness: Intermodalism	
Architecture ATTRIBUTES to Select From	Deployment Coordination versus Independence	Operations Coordination versus Independence	Existing Agency versus New Regional Entity	Information and Advisory versus Command and Control	Independent versus Interdependent User Services	Stand Alone versus Platform based	Degree of Intermodalism of Architecture	Active versus Passive Public Transport in Architecture Services[a]
New York	Moderate Coordination	Moderate Coordination	Existing Agency	Information and Advisory; No Command and Control	Moderate Interdependence	Platform based	Moderate Intermodalism	Moderate Transit Role in Services
Boston	Moderate Coordination	Low Coordination	New Agency	Information and Advisory; Low Command and Control	Low Interdependence	Platform based	Low Intermodalism	Low Transit Role in Services
Houston	High Coordination	High Coordination	New Agency	Information and Advisory; No Command and Control	Moderate Interdependence	Platform based	Moderate Intermodalism	High Transit Role in Services

[a] In Boston's case, public transportation participated in defining the architecture user services, but the prioritized user services do not assign a major role to transit

between regional ITS architecture attributes and the regional needs and objectives. Therefore, findings encompass both architecture attributes and how they match up against regional priorities as defined by long-range transportation plans and improvement programs, and observations about the process of defining a regional ITS system architecture. The latter is of interest because an architecture definition process can provide explanations to the apparent lack of fit between regional characteristics and its architecture. The findings also include illustrative examples from the case studies.

- *Creation of a new regional agency or entity for managing ITS coordination and deployment (rather than an existing agency) enables an architecture definition with broader system functionality.*

Assigning new tasks associated with a system architecture to existing agencies or entities constrains the ITS system functionality because the architecture will be subject to the goals and objectives of the existing entity. On the other hand, using an existing agency makes the task of defining the architecture less cumbersome. TRANSCOM, in the New York case, is an example of an agency that was created for coordinating transportation technology deployments in the New York region before the ITS initiative became national. The architecture developed by TRANSCOM was constrained by the agency's preexisting objectives; however, the architecture was developed quickly and, in fact, has been leading the regional architecture efforts in the United States.

Creating a new regional entity allows for broader architecture supported services, although lack of cooperation of existing agencies can occur. In this scenario, form follows function, as the new entity is conceived to carry out functions enabled by the architecture. Houston's Transtar case illustrates the form-following-function philosophy, whereas Boston still needs to overcome political, institutional, and financial barriers associated with creating the new entity that has been proposed (the TICC in Figure 4).

The authors do not suggest that overcoming institutional obstacles is an easy task; the contrary is true. However, an opportunity for system rearrangement during the architecture definition process may be missed if organizational changes are not considered.

- *A truly strategic regional system architecture for ITS requires major political and institutional support.*

Houston's Transtar has an architecture with a regional strategic character because it created a vision for the region's transportation system and highlighted its relevance to the region's economic well-being. It also served to redefine institutional transportation roles in the metropolitan area by colocating multimodal operations and control centers under one facility. Such a redefinition required strong institutional support from the transit and highway agency, as well as from city authorities.

Using Houston's experience, and given the prevalence of architectures supporting multiple applications—that is, platform-based architectures—architectures can go beyond the traditional role of coordinating deployment to become an overarching regional transportation integrator. Furthermore, an architecture can play a role in helping to make a region competitive because of its use as a planning tool for improvement of passenger and freight transportation systems.

In the other two cases, New York and Boston, the architecture was bound by greater political, institutional, and financial constraints. In the New York City region, the architecture was defined as part of TRANSCOM, which already had a regional strategic mission. In Boston, the architecture achieved a limited strategic and multimodal character constrained mostly by institutional issues. These architectures have not guided a rethinking of regional transportation strategies and institutional roles.

- *Interagency and intermodal coordination can accrue from developing and adopting a regional ITS system architecture.*

Interagency and intermodal coordination can accrue from a regional ITS system architecture. It is difficult to specify an optimal level of regional coordination. Greater cooperation enabled TRANSCOM and Transtar to provide regional coordination that, for example, minimized the transportation network effects of emergency incidents and construction work. Boston proposes to go a step further in assigning limited command and control powers (during emergencies) to the TICC, which is yet to be created.

Figure 5 shows a hypothesized functional form of aggregate transportation benefits versus the degree of regional coordination brought by a system architecture for ITS. The X-axis could be though of as the level of coordination and interagency cooperation in the region.

The authors hypothesize that benefits from coordination grow most rapidly when none or few agencies are coordinated. As the number of coordinated agencies increases, the rate of benefit growth decreases. The optimal point is reached at full integration, where benefits from institutional coordination are maximized. However, moving from an "acceptable" level of integration, depicted by the gray box, to full integration might be very costly in political and financial terms. In the real world, it is suspected that an acceptable point will be found somewhere within the graph's shaded box.

Every architecture studied respects agency autonomy in deciding whether to deploy technologies or not, a feature that yields higher chances of architecture acceptance but at the same time limits regional coordination. Figure 2, 3, and 4, depicting the architectures analyzed, show that for each case the relationship between an ITS coordination center and individual ITS deployment tends to be mediated through a modal agency. On one hand, such a decentralized setup is desirable because a better match between agency needs and the deployment's characteristics can be achieved. On the other hand, respecting agency autonomy and empowering local decision making could hamper reaching a higher system-optimal deployment through coordinated regional deployment. The decentralized decision-making nature of individual ITS deployments appears to be a result of local jurisdictional and political constraints.

- *Thus far, infrastructure intelligence, rather than in-vehicle intelligence, has been a result of the limited participation by private firms in regional architecture developments and definition of user services.*

In the three cases, the processing capabilities or "intelligence" of the user services were consistently assigned to the infrastructure as opposed to the vehicle. Most of the services common to the three case studies, including guidance and travel information services, rely heavily on infrastructure intelligence. This reliance on the infrastructure may be a sign of how the public sector has reacted to the private sector's reluctance to accept a high market risk in a young ITS market. Presumably, the public sector is creating the necessary conditions for the subsequent involvement of the private sector. For example, the Intelligent Transportation Infrastructure (ITI) Program of the U.S. Department of Transportation is a specific attempt to involve the private sector with state and local governments for implementing ITS (*7*).

- *The architectures emphasize suburban mobility through highway transportation and have given limited consideration to public transportation.*

The regional architecture sketches show that the architectures studied assign a high degree of independence to transit agencies in deploying ITS. Such a degree of autonomy increases the risk of incompatible equipment selection and can preclude the agencies from benefiting from regional coordination, support for deploying ITS, and compatibility associated with equipment standards. Houston is an exception regarding ITS transit deployments.

The regional architectures of the case studies and the functions they support concentrate mostly on improving suburban freeway travel. The limited public transportation involvement in both the architecture and ITS deployments is inconsistent with the relevance of transit for at least two of the regions studied, New York and Boston. As suburban trip-making rates are predicted to increase, planning organizations and regional agencies continue making efforts to accommodate the shifting travel demand pattern rather than modify it. The historical prevalence of highway agencies in the transportation arena provides another explanation for the highway emphasis of the architectures.

- *Freight transportation applications are not well-represented by the architecture services.*

Most freight services addressed by the regional architectures are related to regulatory and public safety issues only. Hazardous Material Incident Response and Automated Roadside Safety Inspection constitute, for example, services that concern public safety and therefore have consistently been included in the user services supported by the architectures. However, services encompassing other dimensions of freight operations (e.g., those dealing with efficient intermodal transfers) are not included in either the national architecture or the regional architectures studied. At the regional level this represents a mismatch between the relevance of freight to these three regions and the level of inclusion of freight services in the regional architectures.

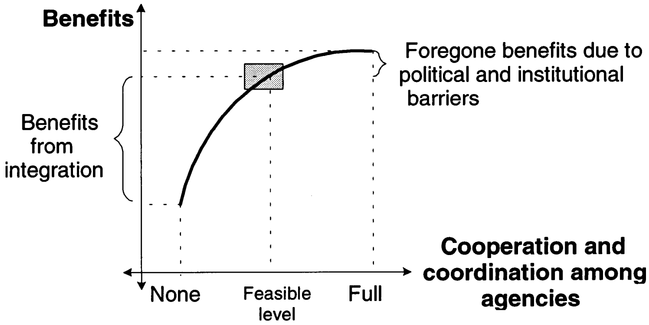

FIGURE 5 Hypothesized benefits of regional coordination and cooperation.

IMPLICATIONS AND NEXT STEPS

A system architecture for ITS can improve the understanding of interaction among transportation components by providing a framework for deploying and operating advanced technologies. These technologies are aimed at facilitating interchange among agencies, infrastructure, and personnel. Parallel to its traditional technical role, a system architecture for ITS can serve broader societal functions. A comprehensive architecture can affect every passenger and freight mode in a surface transportation system. It can be a strategic tool for rethinking roles of institutions, transportation agencies, and transportation services.

The primary contributions of the research conducted to date is a framework for selecting the attributes of a regional ITS system architecture, taking into account regional needs and characteristics. This framework was tested by considering how regional architectures in New York, Boston, and Houston address regional needs.

The framework and the analysis of trade-offs and architecture attributes can serve as seeds for further research in the area of ITS as well as practical guidelines for policy makers and developers of system architectures for deploying advanced technologies applied to transportation. The view that a system architecture for ITS can have regional significance beyond its traditional technology—only orientation is reflected in the architecture definition process proposed (Figure 1). The case studies showed how ITS can motivate the removal of institutional barriers and be an integrator of transportation operations and policies. This broader view requires that societal and transportation needs and goals be identified and understood before a regional system architecture is developed.

The next step in the research involves testing the notion that the National ITS System Architecture can provide a sound base for developing a regional architecture. If regional architectures around the United States use the National ITS System Architecture as a template to address specific needs, national ITS compatibility becomes a more achievable goal. Indeed, the authors suggest that the true test of the National ITS System Architecture is whether or not it can serve as the basis for regional ITS architectures. Once completed, results of the analysis will provide additional information about the architecture development approach proposed.

Evidence from the case studies, particularly the interaction between New York's regional architecture and the National ITS System Architecture, suggests that there is some correspondence between regional architectures and the National ITS System Architecture, and that the latter can be a useful input to the framework. Exporting the framework developed here to various regions can help tie the U.S. National Architecture to localized architecture deployments and can create conditions for having nationally interoperable ITS deployments.

The authors are in the process of applying the framework developed to a real-world case. The framework will be used to select attributes of an ITS system architecture for the city of San Juan (Puerto Rico) in the context of an urban heavy rail project (Tren Urbano) currently being planned.

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